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SURFACE DIAGNOSTICS OF NAROW PLATE MOULDS

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The analysis of the issue of monitoring and diagnostics of surface of narrow crystallizer's desks. There is described the development and the achieved laboratory results based on laser object surface scanning. The diagnostic system which is currently creating will be part of management systems to support service life of mould as a part of continuous steel casting device. The emergence of weariness is caused by many factors, influences and processes that act and run directly on the device, its individual parts, through its operation.

Key words: mould, plate, surface, diagnostics

INTRODUCTION

This paper deal with crystallizer's diagnostics, which is part of continuous casting devices. The diagnostics is made by software analysis of vibration spectrums respectively of acoustics emission. These emissions can cause when unexpected situation occur. Principle of this method is analysis of spectrum of gained signal, its processing in Matlab environment and subsequent verification in Statistica software. Last step is most important, because thanks to it we are able to tell, with certain confidence, in which state the examined object occur. If the initial neural network has good starting data, it is able to analyse other samples and with successfulness over 70 % tell, in which state the current objet remain, eventually if occur a critical (limiting) state (untighten screws in critical spots and so on). [1,2] Data from accelerometer (microphone) are evaluated in Matlab environment and special filter is applied on them. Thos filter will highlight relevant data. Analog signal is digitized with special I/O module from National Instrument company. Type prefix is NI PCI 6221. From FFT result is obvious correlation of power spectrum and the inner state of examined object. Far in this paper will be described process of solving this problematic and current result. To achieve sufficient results, we are using multilayer neural networks with help of Statistica program. Resulting diagnostics system, which should be the final solution, should dramatically innovate and rationalize optimization problems of preventive maintenance of crystallizer's desks, where principle of control on maximum relevant data basis should take apart. Relevant data are obtained from maintenance department.

O. Krejcar, R. Frischer, Faculty of Informatics and management, University of Hradec Králové, J. David, Faculty of Metallurgy and Material Engineering, VŠB – Technical University of Ostrava, Czech Republic.

Main focus is on technical diagnostics of crystallizer. Crystallizer is special device, which can dissipate redundant heat from liquid steel and force it to solidification in predefined profile. In the crystallizer will solidify surface steel layer and feed in the direction of crystallizers output. This process is going together with many unwanted effects, like abrasion of crystallizers walls. Inner wall state is very important quantity, which is closely observed. Too wear crystallizers walls did not dissipate redundant heat well and there is prone to outbreak or to unwanted cracks by heat tension in the surface layer. Technical diagnostics of desks surface is very time consuming process, which require taking out the crystallizer and dismantling it. [3,4]

OBJECTS LIFETIME

The technological systems service life control includes the process and its control when we determine the period of time during which the equipment or its parts are able to perform the required function under given conditions of use and maintenance up to the moment when the limiting state has been achieved. When dealing with this problem it is necessary to be aware of the fact that the meaning of service life term varies in various stages of equipment life cycle therefore we must distinguish the terms as follows:

- Planned technical life - the period of time determined by the designer, during which the equipment has to be able to perform safely and reliably its function; all economic evaluations and as a rule also the permitting procedures are related to the planned technical life (In principle the planned technical life is shorter than the rated technical life of the equipment);
- Rated technical life - the minimum period of time during which the equipment or its parts must be able to perform safely and reliably their functions

under given conditions; this time is determined by means of calculation methods;

- Technical life - the period of time on the expiry of which the limiting state occurs (the technical life is always longer than the rated technical life);
- The total life - the maximum achievable service life of equipment that is terminated by the final retirement of the equipment based on the limiting state;
- The residual life - the period of time during which the technology(or the equipment) can be operated with the required reliability; it is the time left until the technical life or the total life of the equipment have been reached.
- Limiting state - the technical state of the equipment during which the further use of equipment must be interrupted due to an irremovable infringement of safety requirements, irremovably exceeded limits set for parameters, irremovable decrease of operation effectiveness below the admissible level or due to an overhaul execution. [5,6]

EVALUATING METHODOLOGY

The crystallizer is one part the CCE that significantly influences the PLP quality both in view of the internal structure and the surface purity and the dimensional accuracy. The crystallizer service life is influenced first of all by its wear. The physical mechanism of crystallizer wear can be described as follows:

If the surfaces of two functional surfaces (liquid steel or slightly solidified blank's crust and the crystallizer walls) by virtue of the self-weight of steel/blank or the oscillatory mechanism there will be the first contact, theoretically in three points. In these points the real surface pressure is as big as to cause the plastic deformation and parts of surface breaking off (this all in microscopic dimensions). Consequently other places on the parts surface are contacted. On these parts the same processes are running as long as the real contact surface has achieved the level when the real surface pressure does not induce any other deformations. Obviously the achievement of this equilibrium state depends on more factors. For a better description of crystallizer surface wear mechanism it is possible to base it on a general model of the metal polished component surface layer.

The primary goal of this paper is to describe possibilities, when generating 3D surface profile in laboratory environment. For that purpose was used digital SLR camera Canon 650D. As an examined surface serve metallurgical blank from continuous steel casting device with surface defects. These defects are very shallow, maximum depth of scratches do not goes over 1mm, so it is perfect testing object.

For good stability and maximum resolution is needed robust shifting device, which can move the camera and laser together with 1mm or less steps. This is crucial, because distance between the sensing camera and laser line has to be the same over the whole measurement. This shifting device is based on stepper motor with precise motor driver. The shifting length is then depend on pulse count heading into the motor driver. To be able to read all the object's width, it is needed laser line with even line running. In this case was used simple laser line device in price $5. The last is a camera. We used DSLR Canon EOS 650D with standard lens. These core components are sufficient to obtain good quality image series, which can be consequently processed in MatLab environment. [7,8]

RESULTS

We assume, that laser line is much brighter, then rest of the image (Figure 1). The end of the curve is found by the same way. After this first procedure, we should know starting and ending position of inspected curve. These point are very important to speed up whole evaluation process, because we can focused on narrow area around the curve.

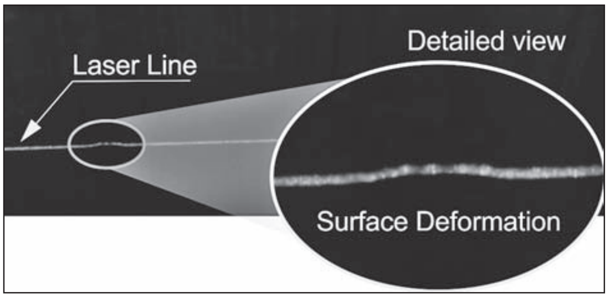

Figure 1 Image of the laser line, deforming it selves on the surface irregularity

It is necessary to reduce laser line width. This is good to improve overall accuracy. Laser line is generated by the laser generator and subsequent optics. Due to lens restriction, the line is not perfectly thin. The good way, how to reduce laser line (curve) is averaging line width along all its length (Figure 2).

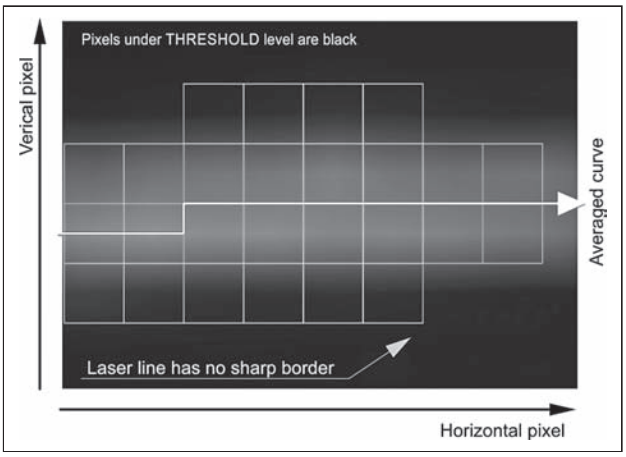

Figure 2 Reducing laser line width to improve surface profile reading

Another important step is aligning the curve in order to be the start point and the end point on the same level. We assume, that start point and end point are on the same level and any inconsistencies are caused by camera optics. [9] The aligning of the curve will improve overall readability of the surface image.

Used algorithm is presented in equation:

$$y_{original} = k \cdot x + q_{=0}$$
$$y_{endpoint} = k \cdot x_{endpoint} \tag{1}$$
$$y_{(i)aligned} = x_{(i)} \cdot \left(\frac{1}{\sum_{startpoint}^{endpoint} x} \right) \cdot (-y_{endpoint})$$

The filter is necessary to applied, because picture of the laser line is not perfect. There are many picture defects, which deteriorate final profile's appearance. The laser line is very bright and that's why not only corresponding camera CCD cells are excited. There are many false pixels around the line, which are affected too. Together with fault camera's CCD cells, imperfection of the optics and fault in laser emitter it makes necessary to use some sort of filter to obtain statistically correct surface's shape. There are many filters, which can be used. Simple averaging of short intervals gives us good results, but in this case has to be used better filter, which can bear in mind some specific conditions of picture behaviour. We developed specific algorithm, which is able to make good results.

Single profile curve is divided into several regions, defined by variable DSP_width. In each region is calculated average value for surface height. Surface curve is presented by $y_{(fx)}$ and actual height by $y_{(i)}$, where i is actual position on the curve. Average value for certain region is calculated by:

$$AVG_{y<n;n+DSP\_wdth>} = \frac{\sum_{n}^{n+DSP\_wdth} y_{(i)}}{DSP\_wdth} \tag{2}$$

This filter should remove random noise added to the profile image and makes it better readable then original raw image. The difference in profiles images, before and after applying the filter, is presented in (Figure 3). [10]

There are several possibilities in MatLab environment, how to plot resulting images. For that given purpose was chose method intended for 2D image, where the profile's height is represented by colour (Figure 3). Of course, 3D visualization model can be used to, but for that purpose images has to be modified to be suitable to visualize surface profile with high resolution details. [11]

CONCLUSION

This paper presented part of the results of experimental grant project, which concern the area of primary cooling system in continuous steel casting device, concretely surface quality of crystallizer's plates. There were presented partial results of methodology of evaluating its quality. In the frame of this article development of laboratory diagnostics system to monitoring narrow plates of the crystallizer were also presented. The focus of the used solution is increasing of advantages of the continuous steel casting device, which can be achieved only by management system's that will minimize undesirable influences on the technological process. Among the significant side effects affecting the efficiency of the process of the continuous steel casting device belong wear of the crystallizer which is causing disturbance and operation disruption.

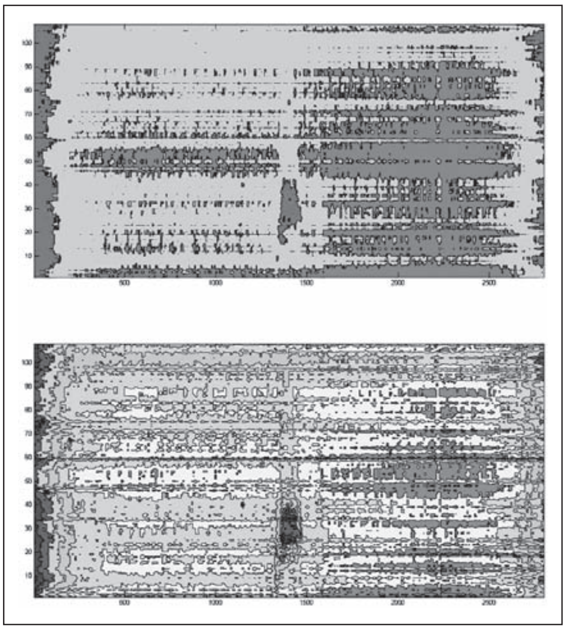

Figure 3 Raw profile visualization and enhanced height resolution after applying digital filter

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Note: The responsible for English language is Stanislava Horakova, Hradec Králové, Czech Republic